

Determining the Minimum Frame Rate for Calculating the Coefficient of Restitution

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Energy and conservation of momentum are common topics for introductory physics courses. The first person to study the effects of energy loss on two balls colliding was Sir Isaac Newton who found that the relative speeds of the balls after they collide to be a fraction of the relative speeds before they collide [1]. He called this value the coefficient of restitution, ϵ . There are many modern experiments that allow for this value to be calculated. One such experiment is to use a microphone and circuitry to find the time between bounces of a ball bouncing on a flat surface. Every time the ball hits the surface, the microphone records the sound. The time between sounds is related to the velocity, which can be used to find ϵ . This is the method that is currently used in the Ithaca College Advanced Laboratory Class.

This past summer, I worked on a new experimental design through the Summer Scholars program here at Ithaca College alongside Dr. Kelley Sullivan. This new experiment has wider uses by being able to test more variables and is inexpensive in comparison. A smartphone camera is used to take slow motion videos of a ball bouncing on a table. A free video analysis program is then used to find the initial drop height and the rebound height. These are related to the velocities via conservation of energy, which can be used to find ϵ .

The motivation for this project came from the fact that this is an inexpensive experiment. With today's technology, it is almost guaranteed that in a classroom of twenty-five students and a teacher, there will be a smartphone and a computer, and at minimum just a meter stick, ball, and camera is needed. This experiment can be done using a bouncy ball from the dollar store. Creating low cost opportunities to explore the field of physics hands on is beneficial because it may help encourage students in school districts with limited resources to gain an interest in science, specifically physics. Students may even be more inclined to enjoy this experiment because they see a bouncy ball and camera, two objects they encounter on an everyday basis, being used for scientific purposes. This can encourage them to further study physics in the future, creating a diverse field with all types of minds contributing.

The goal of my project was to determine if the slow motion setting on a smartphone provided sufficient enough detail to do this experiment or if an expensive slow motion camera with a higher frame rate was needed. I looked at four different frame rates at different pixel qualities including a 30 frames per second (fps) standard video, a 120 fps video, a 240 fps video, and a 480 fps video. The first three frame rates are accessible on a smartphone, while the last frame rate was taken on a more expensive slow motion specific camera.

The results, shown in Figure 1, prove that even a standard 30 fps video provides accurate data for finding the coefficient of restitution. Increased frame rate will give a more consistent answer, but this is not necessary, specifically if this is being done in a high school classroom. These results are powerful because they show that this experiment can be done at essentially no cost. This provides access to a wider range of students who are then able to do and enjoy physics.

References

- [1] R. Cross, "Impact behavior of hollow balls," American Journal of Physics (2014).

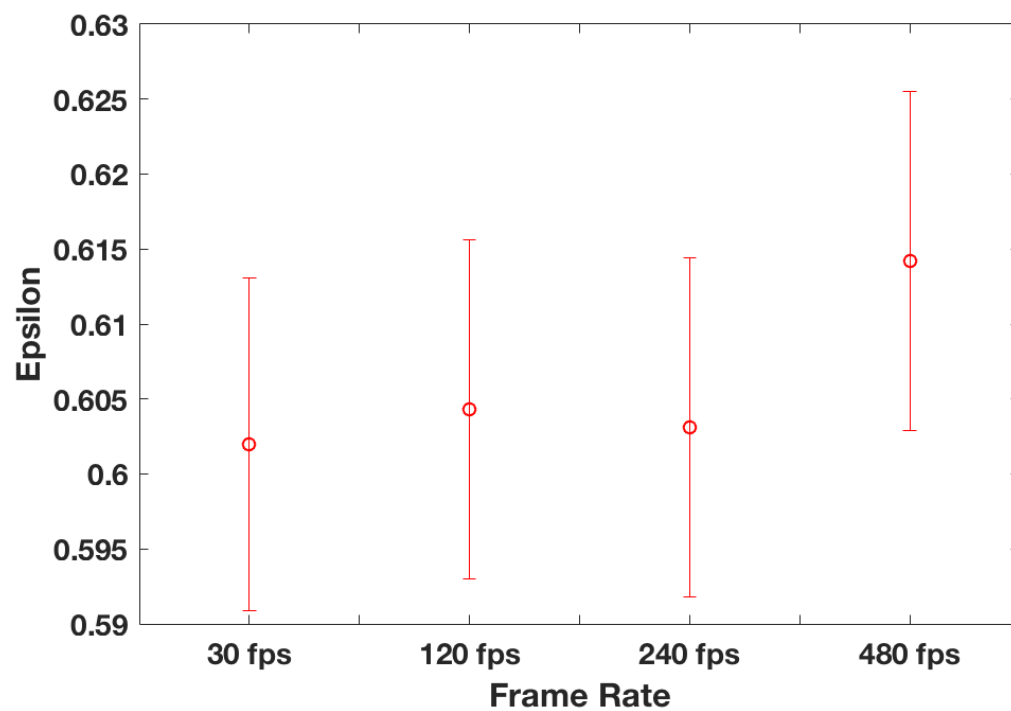


Figure 1: Results: This plot shows the coefficient of restitution, ϵ , as a function of frame rate. There is no "known" value for ϵ , so being consistent is the best we can hope for. Using the 30 fps camera yields the same results as the highest frame rate camera of 480 fps for the height method. This shows that a smartphone is able to be used to perform this experiment.